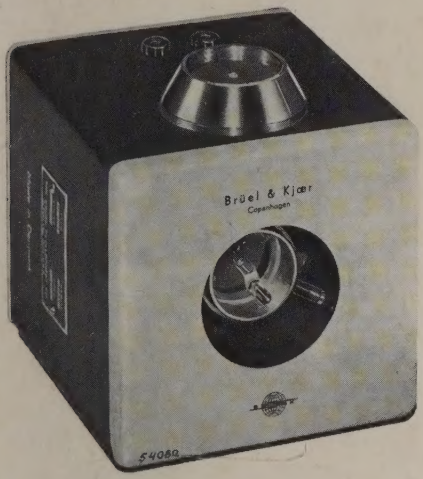
4210

INSTRUCTIONS AND APPLICATIONS

Artificial Voice Type 4210



for the automatic recording of the frequency response characteristic of hearing aids and microphones without using an anechoic room

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ARTIFICIAL VOICE

#2

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DESCRIPTION

The Artificial Voice type 4210 (fig. 1), used in conjunction with our Automatic Frequency Response Recorder type 2314 or our Frequency Response Tracer type 4707, is intended for the recording of the frequency response characteristics of hearing aids and microphones.

Fig. 1. Artificial Voice type 4210.

It consists of a small, specially damped loudspeaker with a fairly flat frequency characteristic in the frequency range from 100 c/s to 5 kc/s, together with a holder for keeping a controlling microphone cartridge centrally placed in the loudspeaker cone. The cartridge can be screwed directly into the aperture, and the microphone pre-amplifier mounting of Microphone Condenser 4111 placed on top of the instrument (see fig. 2).

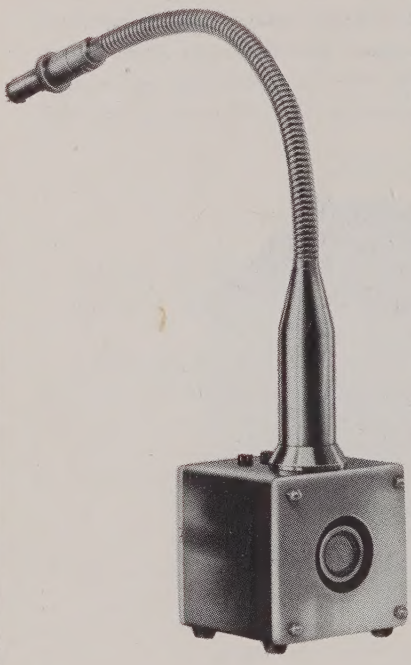


Fig. 2. Artificial Voice type 4210 with inserted controlling microphone cartridge and the Condenser Microphone type 4111 preamplifier mounted on top of the instrument.

The hearing aid or microphone is placed in front of the aperture of the Artificial Voice. It is advisable to have a soft rubber gasket between the Artificial Voice and the object to be tested. For most hearing aids, where the microphone is placed on the front of the apparatus, and in which the sensitive element can be enclosed by means of a ring, as well as with most types of microphones, this condition is easily fulfilled. In other cases measurements should be carried out in a wooden box with thick acoustical lining for the purpose of damping. With regard to the insulation necessary in order to avoid background noise, it is always advisable to carry out these measurements in a box of sufficiently high insulation capacity.

The regulating microphone holds the sound pressure between the two opposing diaphragms constant to within $\pm$ 0.7 db in the frequency range from 100 c/s to 5 kc/s. This is done (see fig. 3) by leading the microphone voltage - amplified by the Microphone Amplifier type 2601 or possibly by the Analyzers 2105 or 2109 - back to the compressor in the oscillator feeding the loudspeaker.

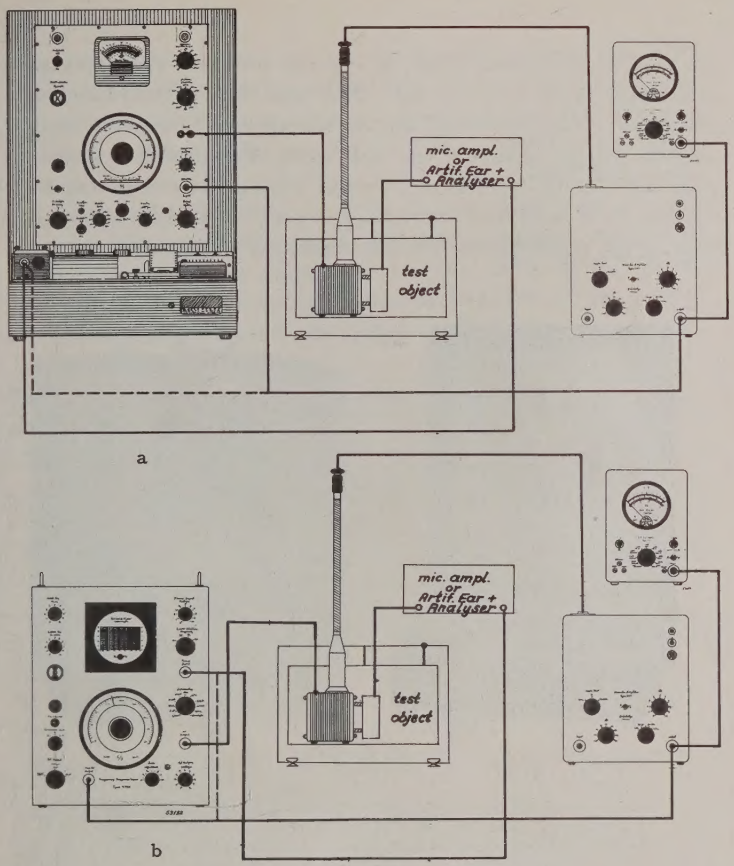
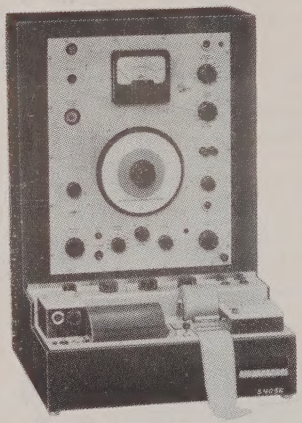


Fig. 3. Standard set-up of Artificial Voice type 4210.
a. With Automatic Frequency Response Recorder type 2314 as signal source and recording system.
b. The same with Frequency Response Tracer 4707.

As signal source, both the Beat Frequency Oscillator type 1012 (shown in fig. 4 as part of the Automatic Frequency Response Recorder type 2314) and the Frequency Response Tracer type 4707 (see fig. 5) can be used.

The compressor in both types can regulate voltages within a range of at least 45 db to a constant value, type 1012 with a speed of 300 db/sec, type 4707 with 200 or 500 db/sec. However, it is only the voltage applied to its input which is regulated to a constant value by the compressor, so that a linear frequency characteristic of the regulating microphone is essential to ensure a constant sound pressure between the regulating microphone and the



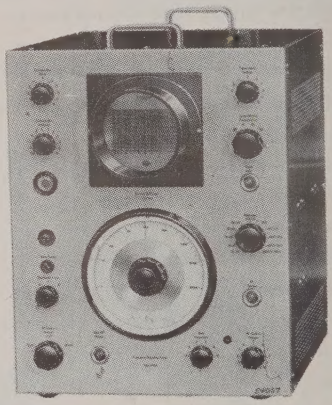
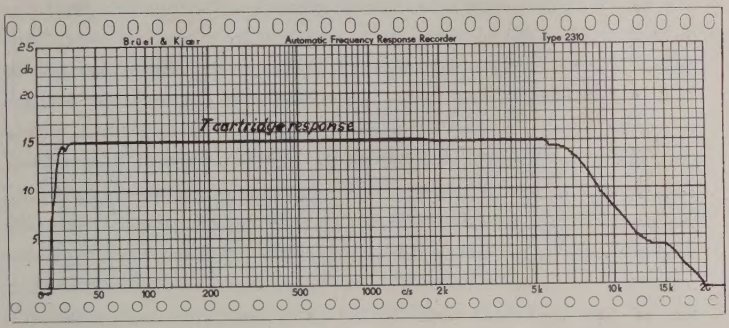


Fig. 4. Fig. 5.

Fig. 4. Automatic Frequency Response Recorder type 2314 consisting of the Beat Frequency Oscillator type 1012 and High Speed Level Recorder type 2304 together as a single unit of 19" width.

Fig. 5. Frequency Response Tracer type 4707 consisting of a built-in beat frequency oscillator, the scale of which, together with a potentiometer for the X-deflection, is driven by a motor, giving the X-axis on the long after-glow cathode ray tube a logarithmic frequency calibration. The output of the equipment being examined is led to the Y-deflection amplifier which has a logarithmic response over a range of 50 db. Scanning speed can be selected to give 3, 6 or 12 scans/min over the whole frequency range, so that the frequency response diagram will be visible for rapid examination, yet with all details.

measuring object. Therefore, a microphone cartridge type 4109 (T-type) belonging to Artificial Ear type 4109 should be used with the Artificial Voice, instead of the cartridge type 4111 (F-type) of Condenser Microphone type 4111. With a constant sound pressure on the membrane the T-type has a linear response between 50 c/s and 5 kc/s within $\pm \frac{1}{2}$ db (falling about 3 db at 20-30 c/s and 7-10 kc/s), while under the same conditions the F-type has a fallling response above 2 kc/s. The reason is that the F-type is constructed for use under free field conditions, where, due to diffraction phenomena, the pressure on the diaphragm rises



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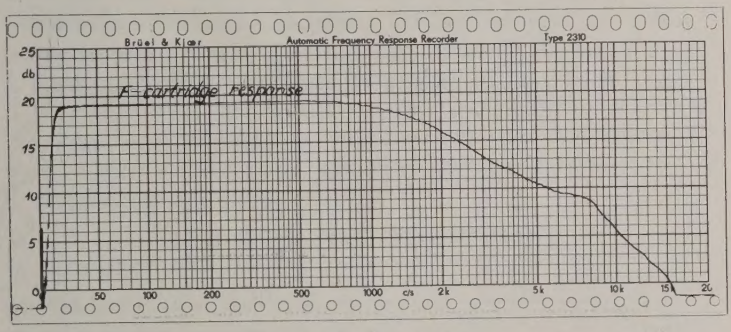


b

Fig. 6. T- and F-type cartridge responses.
a. Response of a T-type condenser microphone cartridge as recorded by means of an electrostatic actuator. (See manual for Microphone Calibration Apparatus type 4120)
b. Response of an F-type condenser microphone cartridge recorded in the same way.

for frequencies over 2 kc/s to about + 10 db at 10 kc/s. The F-type has a falling sensitivity to compensate for this pressure rise, so its response is linear under free field conditions, but falling under constant pressure conditions. Fig. 6 shows clearly this difference between the two types: Fig. 6a shows the response of the T-type cartridge under constant pressure conditions, and fig. 6b shows an F-type cartridge response under the same conditions.

With the BFO traversing the complete frequency range from 20 c/s to 20 kc/s the constant sound pressure (within the given limits)in front of the test object is checked by a method described under Instructions. The response curve of the tested equipment is then recorded on the Level Recorder 2304 or obtained visually on the screen of the Frequency Response Tracer 4707. This second channel from test object to Recorder or Tracer input may consist only of one amplifier, but could just as well contain other transducers and thus necessitate more coupling elements to convert acoustic-input into electric response. For instance with the testing of complete hearing aids the receiver will require an Artificial Ear type 4109 (see fig. 10) to convert once again the receiver's acoustic output into an electric input. The result of such a test then involves the combined responses of the hearing aid's microphone amplifier and receiver (with the coupler of the Ear 4109 as acoustic load in cascade).

INSTRUCTIONS FOR USE

The T-type condenser microphone cartridge is screwed into the aperture of the apparatus and the microphone cathode follower on top of it. The loudspeaker sockets on top are connected up with the output "Load" of Beat Frequency Oscillator type 1012 or "A. F. Output" of Frequency Response Tracer type 4707, and

for impedance matching 6 ohms is chosen. Then, with a connecting cable type 4114, the condenser microphone cathode follower is connected with the input of Microphone Amplifier type 2601 or Analyzer 2105 or 2109, the output of which is led back to the compressor input of the Beat Frequency Oscillator. The instrument to be tested is mounted close to the Voice, taking the previously mentioned precautions into consideration, and connected in an appropriate amplifying circuit, the output of which is recorded by means of Level Recorder type 2304 or Tracer 4707. The recorder is mechanically coupled to the Beat Frequency Oscillator, the frequency range of which, from 20-20.000 c/s, can be traversed with 9 different speeds between 14 secs and 39 hrs. The spot of the Tracer 4707 traverses the same frequency range 3, 6 or 12 times per minute.

Both with Level Recorder and Frequency Response Tracer a check should be made of the B.F.O. compressor's ability to ensure a constant output voltage from the controlling cartridge, and consequently a constant sound pressure in front of the apparatus to be tested, this constancy being dependent on the practical conditions of mounting of the equipment to be tested. To do this, connect the output of the control microphone amplifier (Microphone Amplifier 2601 or Analyzer 2105 or 2109) to the input of the Level Recorder or Tracer, the output of the amplifier still being connected with the compressor input of the BFO in type 1012 or 4707 (see fig. 3). A curve is then recorded, against frequency, for the sound pressure between the regulating microphone and test object. This curve should be constant to within $\pm$ 0.7 db between 100 c/s and 5 kc/s.

At the same time, an absolute measurement of this sound pressure is carried out for one point of the curve, using a Vacuum Tube Voltmeter, e.g. our type 2407 Voltmeter, after the Microphone Amplifier or Analyzer's output, this output still being connected to the Beat Frequency Oscillator's compressor. The compressor of both Beat Frequency Oscillator type 1012 and Tracer

4707 needs two or three volts input to provide a proper regulating capacity. Thus, with the knob "Compressor Voltage" turned to maximum, a constant deflection of about three volts over the full frequency range from 100 c/s to 5 kc/s should be obtained on the Voltmeter. Otherwise, the available power of the Beat Frequency Oscillator is too small and should be increased by the knob "Output Voltage", or the mounting conditions of the tested equipment are unsatisfactory. The latter condition is clearly illustrated in fig. 7 where the upper curve shows a record of the compressor voltage with a hearing aid mounted at 4 mm distance in front of the Artificial Voice, the microphone of the instrument

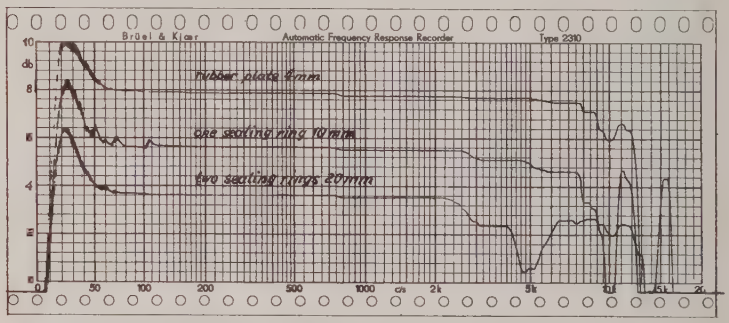


Fig. 7. Influence of mounting conditions on the constancy of the compressor voltage.

under test being sealed to the Voice by a rubber plate with a 4 cm diameter hole. This recording was carried out with a 10 db potentiometer. The lower curves are recorded with the hearing aid mounted with the aid of the same rubber plate plus rubber sealing rings at respectively 10 and 20 mm distance from the front plate of the Artificial Voice. With too big a cavity between controlling microphone and equipment under test, the compressor cannot hold the sound pressure at the diaphragm of the controlling microphone constant, and consequently neither the sound pressure at the tested object. These irregularities increase, the higher the frequency, due to resonances in the named cavity.

Unfortunately, the fairly low input impedance of the beat frequency oscillator's or tracer's compressor input means that we cannot rely on the amplifier's attenuator setting to read the input voltage, and from this, with the aid of the microphone's sensitivity, the absolute sound pressure. The easiest and most accurate procedure for obtaining the sound pressure is therefore to start with the given microphone sensitivity s in mV/μbar, and calibrate the combination loaded Amplifier 2601 - Voltmeter 2407 in advance.

From the beat frequency oscillator attenuator output s mV is led to the input of amplifier 2601, the amplifier output being loaded with both compressor and Voltmeter 2407 (on the 10 V range). The 2407 deflection is then adjusted to 4 db on the db scale, by means of the 2601 attenuators (total amplification about 63 db). A 4 db deflection on Voltmeter 2407 now corresponds to a pressure of 1 μbar, i.e. 74 db re 2.10^{-4} μbar, so that 0 db deflection would correspond to a sound pressure level of 70 db re 2.10^{-4} μbar. (The "Compressor Voltage" knob of the Beat Frequency Oscillator 1012 or Tracer 4707 is turned to its maximum value with this adjustment). Turning back to the original set-up, the applied input sound pressure generated by the Voice can now be read off directly in db on the Voltmeter scale above the value of 70 db re 2.10^{-4} μbar. As 3 volts compressor voltage were necessary, about 10 db will be read off on the Voltmeter, and so with an unchanged setting of the Microphone Amplifier attenuators, the sound pressure level of the Voice will be about 80 (70 + 10) db. As the compressor holds the output from the amplifier constant, increasing or decreasing the amplifier's gain means that its input will vary the same amount in the opposite direction, and consequently the sound pressure level of the Voice also. Thus, with Amplifier 2601 with an additional 17 db gain left (the maximum gain is 80 db whereas it is assumed that the adjustment described requires an amplification of 63 db) the lowest sound pressure which can be kept constant with Microphone Amplifier 2601 in the given set-up is about 63 db re 2.10^{-4} μbar

(80-17 db). The upper level for the sound pressure is fixed by the maximum output of the beat frequency oscillator, and is about 120 db (amplifier gain about 23 db).

If sound pressure levels lower than 63 db are required the same set-up can be used, but now the compressor voltage is taken from the output of the voltmeter instead of from the amplifier, to make use of the voltmeter's extra gain. On its 10 V range the voltmeter gives no extra amplification, but on the 3 or 1 volt range the instrument gives an additional 10 or 20 db amplification which suppresses the Voice's sound pressure level to respectively about 53 and 43 db re 2.10^{-4} µbar. Care should be taken here to insulate the Voice sufficiently in order that the background noise does not interfere with the measurement at the low level. The same adjustment with the aid of s mV from the beat frequency oscillator attenuator to the amplifier input should be carried out as above described to obtain 70 db sound pressure level for the voltmeter's 0 db scale deflection value.

Should one of the Analyzers 2105 or 2109 be used as amplifier for the compressor voltage, the same adjustment as above should be carried out to obtain the sound pressure level of the Voice. With the analyzer's output selector on "Level Recorder" and the beat frequency oscillator compressor input + a VT voltmeter as load, s mV is put on the input of the instrument. With the sensitivity adjustment of the analyzer the deflection of the voltmeter is now regulated on 4 db. Then 0 db meter deflection corresponds to 70 db S. P. L. re 2.10^{-4} µbar, whereas about 80 db S. P. L. of the Voice will be obtained with the analyzer's amplification unaltered. ("Voltage Range" knob then on -60 db.). A reserve of 20 or 40 db amplification is now available to suppress the S. P. L. of the Voice to about 60 or 40 db re 2.10^{-4} µbar.

Lastly to adjust the sound pressure level to an accurate arbitrary value the "Compressor Voltage" knob is used.

Screwing this knob back results in an increase of the compres-

sor input voltage and consequently of the Voice's sound level. Multiples of 10 db sound pressure level can thus be obtained exactly and set to an appropriate line of the recording paper.

For instance the sound pressure level of 70 db re 2.10^{-4} μbar shown in fig. 16 used with the microphone test was obtained using an Analyzer 2105 as amplifier. After adjustment with Voltmeter 2407 on the output and s mV on the input to obtain a 0 db voltmeter reading for 70 db sound pressure level, the Voice's output was 81.5 db without altering the analyzer's gain (-60 db on "Voltage Range") and with maximum position of "Compressor Voltage".

Increasing the amplification 20 db (-80 db for "Voltage Range") decreased the sound pressure level to 61.5 db, and then the "Compressor Voltage" was screwed down so far as to give an exact 20 db deflection on the voltmeter, corresponding now with 70 db sound pressure level.

For accurate calibrations two corrections can easily be taken into account. First, the compressor regulates its input voltage to a constant value. Therefore the possible small variations within 1 db around the linear frequency response curve from the regulating microphone should be subtracted from or added to the recorded sound pressure curve in order to find the real sound pressure in front of the test object. For example, a positive rise on the microphone response curve will thus mean a negative dip in the actual sound pressure level in front of the test object. Thus, this correction can be directly added to the recorded curve of the measured object to find the response to real constant sound pressure.

Secondly, for an accurate absolute measurement of the sound pressure, it should be noted that the microphone sensitivity, as specified on the calibration curve for the microphone cartridge used, is slightly decreased when the cartridge is used in the Artificial Voice type 4210, because of the increased parasitic capacity which

is introduced with the extended connection between the cartridge and microphone pre-amplifier 4111.

This attenuation (about 1 db) subtracted from the sensitivity of the cartridge gives the sensitivity of the Artificial Voice under actual working conditions.

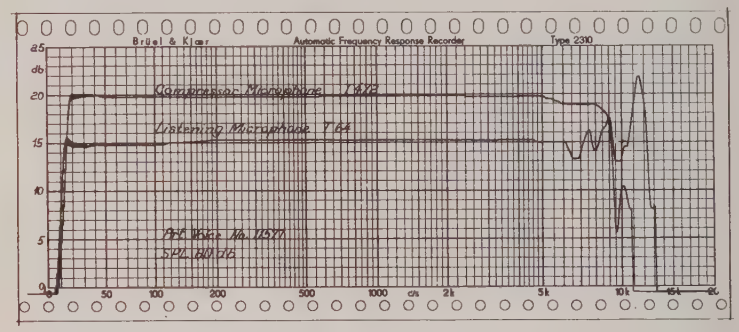


Fig. 8. Double recording of compressor voltage or S. P. L. at controlling microphone and the response of a listening microphone mounted 5 mm in front of the Artificial Voice. Both controlling and listening microphone are equipped with T-cartridges with linear response curves within o. 2 db between 50 c/s and 5 kc/s (the response of cartridge T472 is given in fig. 6a). For the sake of distinction only the curves are set 5 db apart, but the sound pressure levels existing between the two microphones as measured through the two different channels (Microphone Amplifier 2601 + Voltmeter 2407 for the controlling microphone and Analyzer 2105 for the listening microphone) only differ by 1 db.

As an example of a compressor voltage and S. P. L. recording, as well as an illustration of how the Artificial Voices are checked before delivery, the recording of fig. 8 is given, taken with Level Recorder 2304 and a 25 db potentiometer. The test set-up consists of the following instruments: Frequency Response Recorder 2314, Microphone Amplifier 2601 for the amplification of the compression voltage delivered from the controlling T-cartridge of the Artificial Voice 4210 via cathode follower 4111, Analyzer 2105 as amplifier for a second Condenser Microphone 4111. This last is equipped likewise with a T-type microphone cartridge mounted

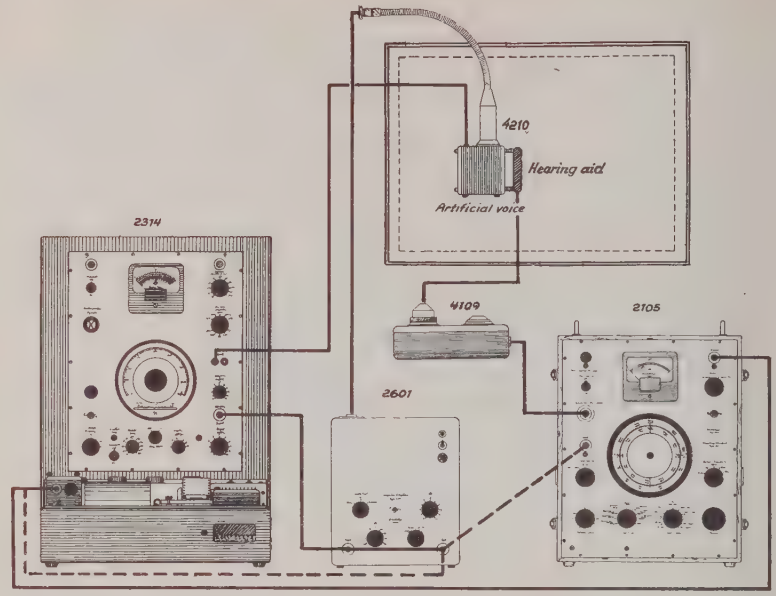
0.5 cm in front of the Voice, placed in a soft rubber plate covering the whole front plate of type 4210. Both T-cartridges have rectilinear response curves within 0.2 db between 50 c/s and 5 kc/s. The upper curve shows that the compressor of the beat frequency oscillator can hold the voltage delivered at its input constant within 0.2 db between 50 c/s and 5 kc/s. The lower curve shows that also the sound pressure in front of the instrument, sealed with the rubber plate as described, is constant within 0.5 db. The permitted tolerances for this last curve are $\pm$ 0.7 db. The S.P.L. at 400 c/s as measured with the compressor cartridge and the combination Amplifier 2601 and VT Voltmeter 2407 adjusted as described above and taking the 1 db attenuation of the Voice into account) amounts, in this example, to 80 db re 2.10^{-4} μbar. Through the second channel, that is Analyzer 2105 (adjusted in the normal way by means of the built-in reference voltage of the instrument), the listening Condenser Microphone 4111 measures, at 400 c/s, a S.P.L. of 81 db. This sound pressure is read off in db re 2.10^{-4} μbar as the sum of the "Voltage Range" phon index + db reading on scale + a factor $K = 20 \log. \frac{5}{s}$, in which s is microphone sensitivity in mV/μbar. (See Manual 2105). (For the sake of distinction only, the curves in fig. 8 are set 5 db apart).

Now, with a recorded compressor curve of satisfactory constancy and the S.P.L. measurement of the acoustical input for the test object carried out. the recording of the frequency response of the instrument to be checked can take place. Different examples of complete set-ups follow now in the applications.

APPLICATIONS

RECORDING THE RESPONSE OF COMPLETE HEARING AIDS

Fig. 9, a and b, shows the set-up for recording the frequency response of a complete hearing aid, and an example of a com-



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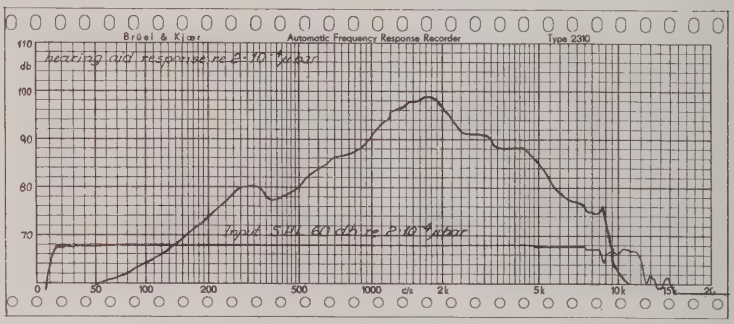

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Fig. 9.

a. Set-up for the recording of the frequency response characteristic of complete hearing aids.

b. Example of complete recording.

Fig. 10. Artificial Ear type 4109. The 2-cc coupler for hearing aid receivers is seen at the right side and the NBS coupler for telephone receivers with damping grid for the higher frequencies at the left.

plete recording. The different connections from the Artificial Voice to the oscillator and the recording part of the Automatic Frequency Response Recorder type 2314, as well as the Microphone Amplifier 2601, are described in the instructions for use. The receiver of the hearing aid, lying outside the insulating box, is placed on the Artificial Ear 4109, constructed in accordance with the American Standards Z. 24. 9. The 2-cc coupler of this instrument is used for insert earphones, while an interchangeable 6-cc A. S. A. or 5-cc coupler according to the National Bureau of Standards model can can be used for bigger telephone receivers (fig. 10). The Artificial Ear is fitted with a T-type cartridge and cathode-follower, the output of which can be led to an Analyzer 2105 or 2109, or Microphone Amplifier 2601. The output of one of these last instruments is in turn connected to the input of the level recorder.

An Analyzer 2105 is employed in this set-up, as one of the basic measurements on hearing aids is that of the distortion, which can be carried out for a suitable number of frequencies directly after the recording of the frequency characteristic, and noted in the same record. Analyzer 2105 (fig. 11) is of the constant percentage bandwidth type, with variable selectivity of from 20 to 40 db attenuation 1 octave off tuned frequency in steps of 5 db, and tunable between 47 and 12. 500 c/s. A whole series of hearing aids can now be checked only by interchanging hearing aid amplifier and receiver in this set-up. Only one recording of the sound pressure in front of the hearing aid microphone will then be necessary and is simply carried out by connecting the input

of the level recorder with the output of Microphone Amplifier 2601. Instead of Analyzer 2105, the 1/3 octave Analyzer type 2109 can also be used. This instrument is employed in the set-up of fig. 12 where more details follow.

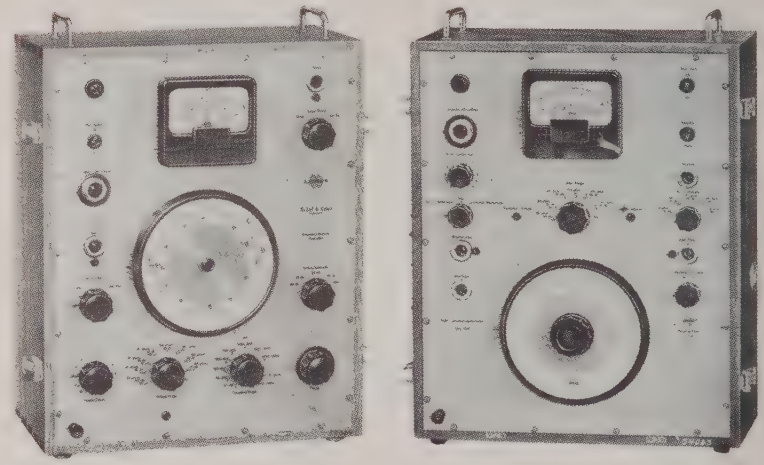


Fig. 11. Constant Percentage Bandwidth Analyzer 2105. and 1/3-Octave Analyzer 2109.

The sound pressure measurement of the acoustical input follows as above described with the aid of a vacuum tube voltmeter connected to the output of Amplifier 2601, for which measurement Analyzer 2105 (set to linear 10 V range) can now simply be taken, as shown by the dotted line in the set-up. It will be an advantage to have as sound pressure a multiple of 10 db to test the different instruments with. In that case the acoustic gain of the apparatus can easily be read off from the recorded curve. Decreasing the setting of the compressor voltage knob, which results in an increased sound pressure level of the Voice, makes it always possible to regulate the Voice's sound pressure up to an exact multiple of 10 db. The curve of the recorded S. P. L. can then be set to an appropriate line of the recording paper. Thus in the example of fig. 9b the applied sound pressure on the hearing aid was adjusted to 60 db re 2.10^{-4} ubar.

The sound level which the hearing aid receiver produces in the coupler of the Artificial Ear is directly measured on the meter of Analyzer 2105. The sound pressure level in db above the reference value 2.10^{-4} µbar is in this case (see manual 2105) meter reading in db + attenuator setting in phon + a factor K = 20 log. $\frac{5}{s}$, where s is the sensitivity of the artificial ear, i.e. the combination of T-cartridge and the pre-amplifier in type 4109. Here again, the absolute level of one point of the response curve (advisably the maximum point found by traversing the frequency range manually on the BFO 1012) should be measured and set on an appropriate line of the recording paper. With the input sound pressure recorded on the 10 db line, and the maximum acoustic gain of the hearing aid not exceeding about 40 db, the same ordinate scale can be used, otherwise the attenuator of the analyzer can be used to reduce the amplification during the second recording by 10 or 20 db, and consequently increase the ordinate scale values by the same amount. In this way one record combines the complete characteristics of input and output sound pressures, absolute levels and acoustic gain of the hearing aid tested, all in db re 2.10^{-4} µbar versus frequency.

VISUAL CONTROL OF COMPLETE HEARING AIDS

The set-up for visual control of hearing aids is shown in fig. 12. The oscillator part of the Frequency Response Tracer 4707 is connected in exactly the same way as before. The response of the hearing aid is now - via Artificial Ear 4109, and amplified by the Analyzer 2109 - led to the "Tracer Input" to provide the vertical deflection on the C. R. T. A logarithmic amplifier for the vertical voltage of the C. R. T. gives a log. Y coordinate from 0-50 db. Checking the applied sound pressure on the hearing aid as well as its absolute measurement follows according to the dotted lines in the set-up. In this case the tracer spot follows a horizontal line to $\pm$ 1 db from 100 c/s to 5 kc/s.

In fig. 13a the complete set-up for visual hearing aid testing is

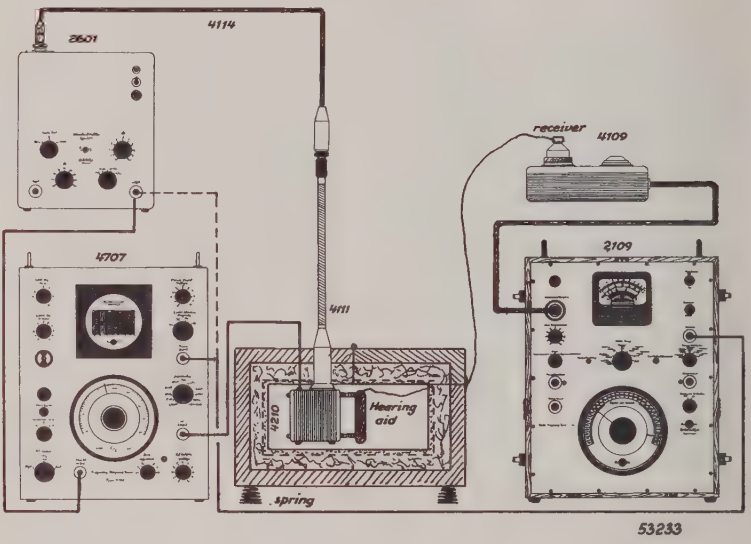


Fig. 12. Visual control of hearing aids with the Frequency Res-- ponse Tracer type 4707.

depicted. In the upper row of the photograph, the Microphone Amplifier 2601 for the controlling microphone is shown, together with Constant Percentage Bandwidth Analyzer 2105, for the amplification of Artificial Ear type 4109. This latter stands on top of the insulating measuring box of 15 mm wood with acoustical lining for damping purposes. Inside the box is Artificial Voice 4210 with T-cartridge mounted inside and pre-amplifier 4111 on top. Finally Frequency Response Tracer 4707 is seen in the right corner with "AF Output" at the right hand side lower part leading to the loudspeaker of 4210, "Compressor Input" coming from the Microphone Amplifier 2601 output and "Tracer Input"

coming from the Analyzer 2105 output. The result of the test is depicted photographically again in fig. 13b and 13c. Fig. 13b shows the tracer spot curve for the compressor voltage, fig. 13c the one for the complete hearing aid.

The measuring box as depicted in fig. 12 and 13a should be made of thick heavy material, e. g. 2" laminated plywood, with 1 1/2" rockwool or glasswool covered by a perforated steel lining. A hinge lid makes quick changing of the hearing aids possible, Shock absorbers are fitted to avoid transmission of impact waves. Such a construction, tested on both airborne sound insulation and vibration insulation gave as result fig. 13. The airborne insulation was measured with the aid of a Condenser Microphone type 4111 as the level difference inside and outside the box and the vibration insulation with the aid of our Pick-Up type 4304 and Integration Network 1604 as the level difference between velocity amplitude of the supporting surface and the perforated lining in the box.

In the set-up of fig. 12 the Audio Frequency Spectrometer 2109 has been used instead of Analyzer 2105. This instrument has 27 filters of 1/3 octave bandwidth for the standard frequencies 40-50-63.....up to 16000 c/s, allowing distortion measurements up to the 5th harmonic without any tuning. The very steep curves of these filters allow the determination of distortions down to 0. 3% for the 2nd harmonic, and still smaller for the higher harmonics, while Analyzer 2105 with maximum selectivity of about 40 db one octave from the tuned frequency can only measure 2nd harmonics greater than about 1%. The greatest advantage, however, of Analyzer 2109 in these set-ups is shown in fig. 15, i. e. for the direct recording of harmonics.

DIRECT RECORDING OF HARMONICS

The set-up of Automatic Frequency Response Recorder 2314 and Audio Frequency Spectrometer 2109 in fig. 15 allows a continuous

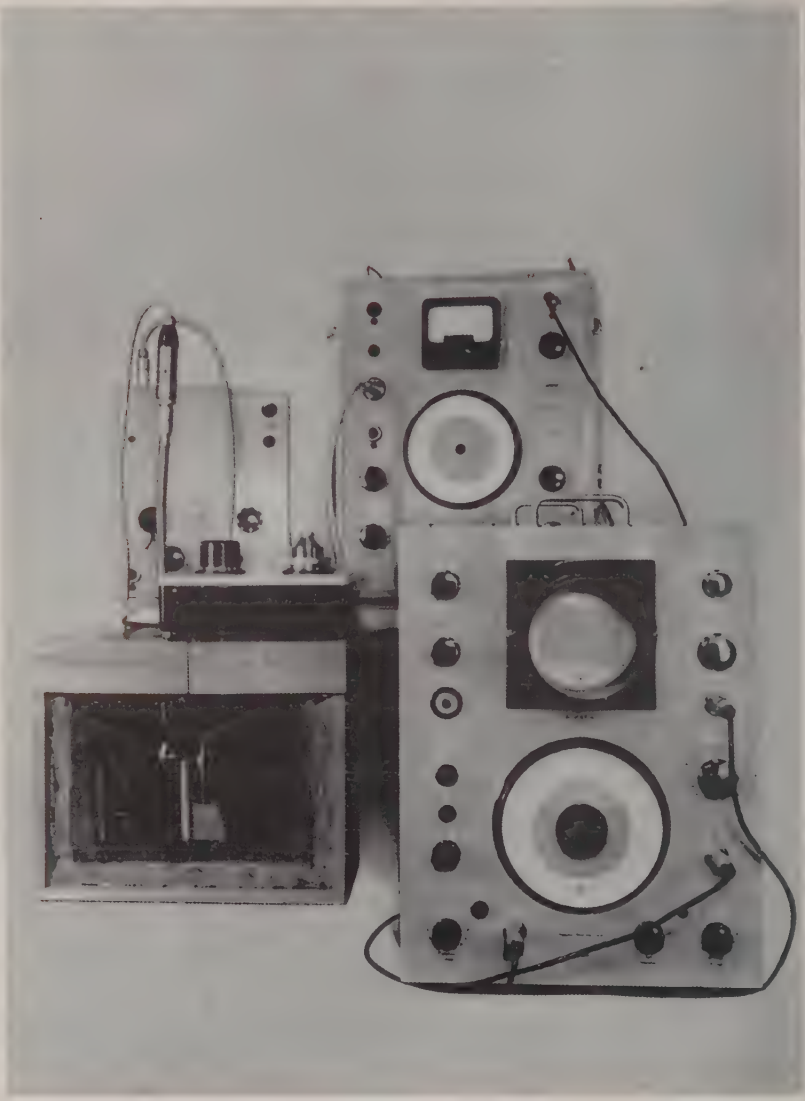
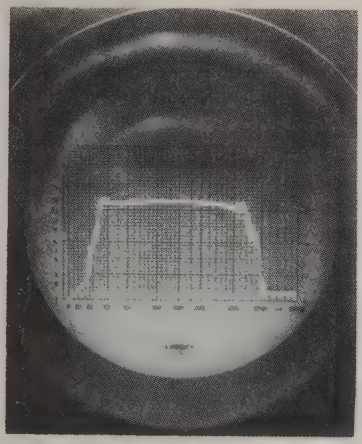
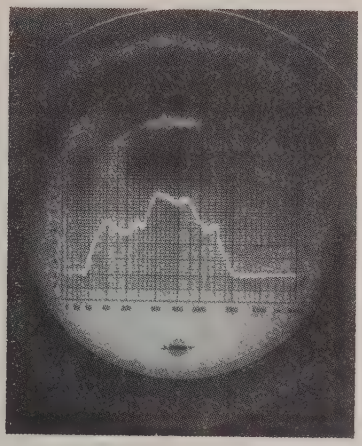


Fig. 13a. Complete set-up for visual control of hearing aids.





b c

Fig. 13b. Photo of tracer spot for the compressor voltage or constantly-held sound pressure.

Fig. 13c. Photo of tracer spot for a complete hearing aid.

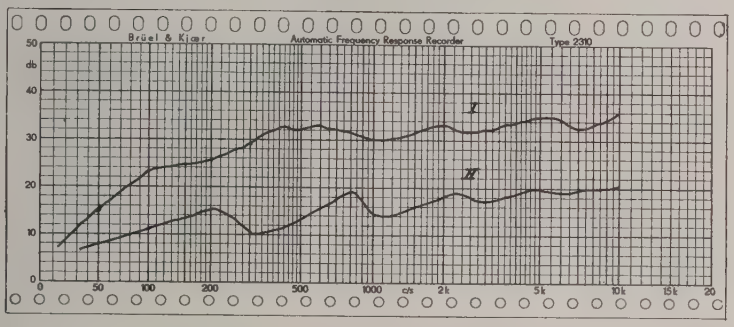
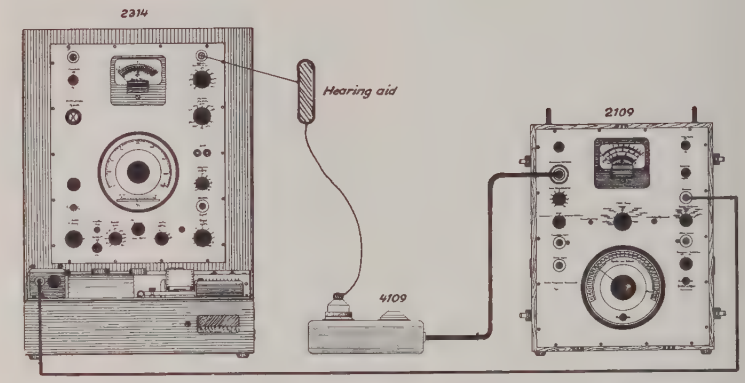


Fig. 14.

I. Airborne sound insulations defined as the ratio between sound pressure outside and inside the box.

II. Vibration insulation of impact waves defined as the ratio between the velocity amplitude of the vibration of supporting surface and the perforated lining in the box.



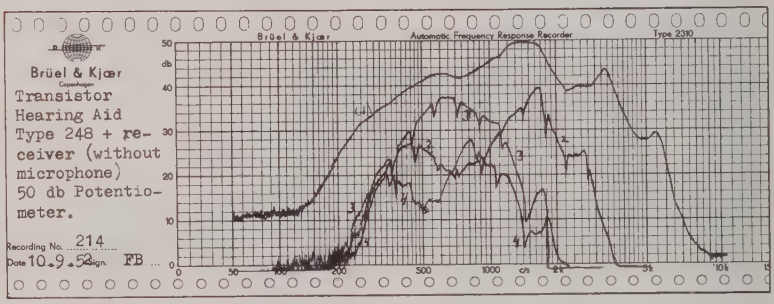


Fig. 15. Direct recording of fundamental, 2nd, 3rd and 4th harmonics of a hearing aid amplifier plus receiver.

recording of 2nd, 3rd, 4th and 5th harmonics. In this example the distortion is measured of a hearing aid without microphone, with a direct electrical input to the first transistor, but fundamentally there is of course no difference introducing also here Artificial Voice 4210, and applying an acoustic input to the complete hearing aid.

The method consists in that after the normal frequency response

curve of the equipment has been taken, where Analyzer 2109 is used as a normal linear amplifier, the recording paper on the level recorder is rolled back, whereupon a second traversing of the complete frequency range is performed with slower paper and traversing speed, but with the spectrometer now selectively used, being manually set to a frequency one octave higher than the BFO frequency to obtain the 2nd harmonic, 1 1/2 octaves for the 3rd harmonic, 2 octaves higher for the 4th harmonic, and so on. The shifting from one filter to the other is done manually at frequencies which are noted in advance and which should be followed very carefully. These shift frequencies are given in the manual for the Spectrometer 2109 together with more details about this measurement.

CHECKING OF MICROPHONES

This is easily followed from fig. 9 by replacing the hearing aid-Artificial Ear 4109 combination by the microphone to be tested. Emphasis should be laid in this check on the advisability of having a sealing between the microphone to be tested and the artificial voice. In this way the microphone will be tested under constant pressure conditions, using as normally is the case, a T-cartridge for the regulating microphone, which with its linear frequency range between 50 c/s and 5 kc/s gives a constant sound pressure between the diaphragms of the regulating and checked microphone. The better the sealing between the two diaphragms and the closer the distance, the nearer will constant pressure conditions be approached. (The accuracy of the method can be increased by taking into account the small variations in the linear frequency characteristic of the regulating microphone as already explained on p. 11).

Fig. 16 shows the result of such a test with a double recording of input sound pressure level recorded on the 10 db line of the paper and the response in db re 1 volt of the tested microphone.

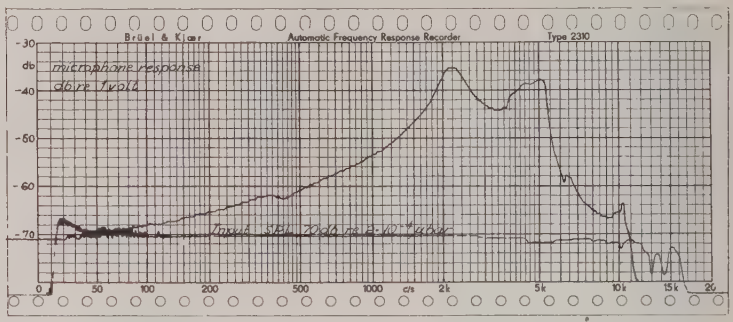
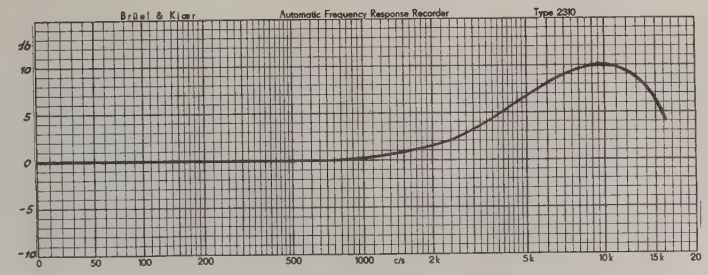


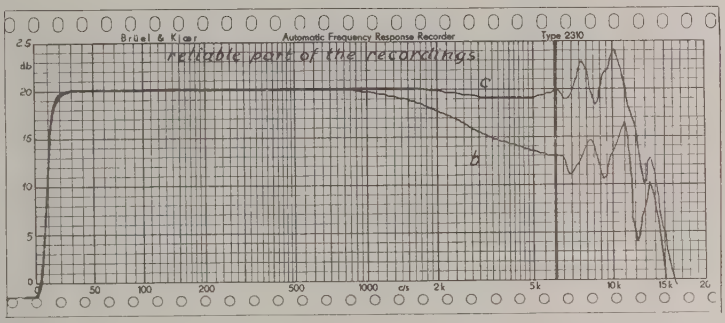
Fig. 16. Recording of both the input sound pressure level applied to a crystal microphone and its response. The sensitivity in db re 1 volt/ μbar follows from the upper curve when 4 db are added to the coordinate values.

The sensitivity S of the microphone follows directly from these two curves. The maximum response at 2200 c/s was -36 db re 1 volt/ μbar for an input S. P. L. of 70 db over 2.10^{-4} μbar. Consequently the maximum sensitivity is S = - 36 - 70 + 74 = -32 db re 1 volt/ μbar.

The response of a microphone as well as a hearing aid under free field conditions, i. e. with the test object placed in a free sound field with, for all frequencies, a constant sound pressure level prior to the introduction of the transducer in the sound field, is different from the response under pressure conditions. This difference is smaller the smaller the dimensions of the tested equipment are compared with the wave length of the incident sound. For simple geometrical forms the difference between pressure and free field response can be theoretically calculated. This has been done for example for our Condenser Microphone type 4111. For hearing aids in which the dimensions are simple these computations are also possible. But even these data will not give sufficient information about the hearing aid response under ac-



a



b

17a. The difference between free-field and pressure response in db versus frequency for Condenser Microphone 4111.

17b. Curve b. Pressure response of a Condenser Microphone 4111 as recorded with the aid of Artificial Voice 4210.

Curve c. Free-field response of a Condenser Microphone 4111 as recorded with the aid of Artificial Voice 4210.

tual working conditions when the hearing aid is being worn in use. The baffle effect of the wearer of the hearing aid will for example cause additional diffraction effects in the free field, so that the only completely reliable test results are obtained under free field conditions with a baffle around the hearing aid having the form of the average human wearer. This body baffle effect

has been treated by several American authors[x]. Suppose now that with an arbitrary model of hearing aid or microphone the difference between pressure and free-field response is known, either by theoretical calculations or by measurements carried out on actual baffles in a free field. Then, by introducing a network between the amplifier of the controlling microphone and the compressor input of the B. F. O. the damping characteristic of which equals this difference between the pressure and free field response curves, an increased sound pressure will consequently be produced in front of the regulating microphone, as the compressor voltage is the one and only parameter held constant. This is valid only with one limiting factor, that is that the difference between pressure and free field response may not exceed 30 db, otherwise the compressor will be unable to hold its input voltage constant, as it is now compensating both the loudspeaker fluctuations and correction network damping over the complete frequency range.

As an illustration of the described principle fig. 17a shows the difference between the free field and pressure response in db for Condenser Microphone 4111, this difference only being dependent on the dimensions of the microphone housing. When this microphone (equipped as normally is the case with a F-type cartridge) is checked with the Artificial Voice using the normal procedure, fig. 17, curve b, will result, showing thus the pressure response. Introducing a correction network with a frequency characteristic which is the inverse of fig. 17a, resulted in the recording shown in fig. 17b, curve c, i.e. the free field response of the microphone. This example is of course only given as an illustration

x)
Wilbur W. Hanson: "Baffle effect of the human body on the response of a hearing aid". Journal of the Acoustical Society of America, 16, 60 (July, 1944).

R. H. Nichols, Jr., Marquis, R. J. W. C. Wiklung, A. S. Filler, C. V. Hudgins, and G. E. Peterson: "Influence of body-baffle effects on the performance of hearing aids". Journal of the Acoustical Society of America, 19, 943, (November, 1947).

of the method described, to show that even the free field response of a microphone can be obtained with the Artificial Voice 4210. In practice, for the highly accurate condenser microphone, both pressure and free field calibrations are carried out in completely other ways, respectively the actuator method with and without correction filter, or, real free field measurement (see manual for the Microphone Calibration Apparatus type 4120).

ADDENDUM

Why constant-pressure characteristics instead of free field response.

In most of the standards or tentative standards laid down for measurements on and control of hearing aids[xx], it is prescribed that

[xx] American Standard Method for Measurement of Characteristics of Hearing Aids. Z. 24. 14-1953.

British Standards Institution: Statement of Present Position in the United Kingdom regarding Methods of Measurement of Hearing Aid Performance.

Nederlandsch Electrotechnisch Comité: Comments from the Nederlands Electrotechnical Committee on the A. S. A. Standard Z 24. 14-1953.

Le problème de la Normalisation des Appareils de Prothèse Auditive et des Méthodes de Mesure par MM. R. Chavasse et R. Lehmann. Acoustica, Vol. 2, p. 119.

the frequency characteristic be recorded under free field conditions, often with a specified sound level which is so low that the apparatus must be measured with the amplifier working at its highest level.

As seen from the foregoing, the frequency characteristic is measured with constant sound pressure when the Artificial Voice 4210 is used. The question therefore arises whether it would not be better to work out a method where the hearing aid was measured under free field conditions, in complete analogy with current standards. If it were only a question of investigating a single piece of apparatus in a first class fully equipped laboratory, it would perhaps be natural to use the laboratory's anechoic room and record the free field characteristics, but for the routine examination of large numbers of apparatus, free field measurements would be very impracticable.

1. Free-field measurements demand an anechoic room, which is expensive to construct, and must be sited in a noise-free building so as to keep down disturbing noise. For reasons of economy and space, only the fewest factories can consider such an installation.

2. Free field measurements take a long time to carry out, as one is forced to run in and out of the anechoic room with the equipments to be measured, and the measurements must often be made at night, outside working hours, so that reasonable noise-free conditions can be obtained.

3. The curves obtained with free field measurements are usually very irregular in appearance, for even in a good anechoic room disturbing reflections arise from the walls and between the hearing aid and the comparison microphone. This irregular, jagged shape has no great significance in a large acoustic laboratory, where the curve is interpreted by trained personnel, but with routine mea-

surements these irregular curves are very disturbing. In free field measurements these irregularities often amount to ± 2 to 3 db, while in practical production the permitted limits are set at ± o. 5 db. Thus, some practice is needed to be able to insert a mean curve for the results of free field measurements, and estimate this with ± o. 5 db exactitude. On the other hand, recordings of pressure characteristics yield an even and perfectly reproducible course (see fig. 8 for the applied sound pressure and 9b for the pressure response of a hearing aid), which facilitates the estimation to a high degree.

4. The problem of sound insulation is a very serious one for practical work with free field measurements, while pressure measurements can be made relatively easily and cheaply in an insulated box, as shown in fig. 12. As can be seen in fig. 14, a considerable reduction in the noise level can be achieved simply by means of attention to the insulation of the measuring box. Furthermore, the hearing aids can be quickly exchanged, and it is possible to carry out measurements at practically any place in a factory or other building, making it unnecessary to transport the hearing aids over longer distances during the manufacturing process.

5. As mentioned, the difference between the pressure and free field characteristic depends only on the hearing aid's physical dimensions and mechanical construction, so that, if one has once and for all established this difference for one particular type, one can always establish the free field characteristic from the pressure characteristic, and vice versa.

Specification.

Principle: Heavily damped loudspeaker with output regulated by condenser microphone cartridge type 4109 (belonging to Artificial Ear type 4109).

Frequency Characteristic with Regulator: Flat within ± 0,7 db in the frequency range from 100 c/s to 5 kc/s with the aid of the automatic volume regulator in the Beat Frequency Oscillator type 1012, or the Automatic Frequency Response Recorder type 2314, or Frequency Response Tracer type 4707.

Frequency Characteristic without Regulator: ± 7 db in the range from 100 c/s to 5 kc/s.

Aperture: Diameter is 6 cm.

Sound Pressure: With the Beat Frequency Oscillator type 1012 with 2,5 Watt max. output a sound pressure between 50 and 120 db re 2.10^{-4} microbars is obtained.

Distortion: Less than 1 % in the range from 100 c/s to 5 kc/s for pressures lower than 1 microbar.

Apparatus required for Recording Frequency Response Characteristics of Hearing Aids or Telephone Sets: Automatic Frequency Response Recorder type 2314 or High Speed Level Recorder type 2304 plus Beat Frequency Oscillator type 1012, Artificial Voice type 4210, Artificial Ear type 4109, the cathode follower of Condenser Microphone type 4111 and two Microphone Amplifiers type 2601.

Recording of Frequency Response of Microphones: Automatic Frequency Response Recorder type 2314 (or 2304 plus 1012), the cathode follower of Condenser Microphone type 4111, Artificial Voice type 4210, Microphone Amplifier type 2601 and a suitable amplifier for the microphone under test. The gain of this amplifier should be such as to give at least 10 mV output to the level recorder for the lowest level to be recorded.

Control of Frequency Response of Hearing Aids and Telephone Sets: Frequency Response Tracer type 4707, Artificial Voice type 4210, the cathode follower of Condenser Microphone type 4111, Artificial Ear type 4109 and two Microphone Amplifiers type 2601.

Control of Frequency Response of Microphones: Frequency Response Tracer type 4707, Artificial Voice type 4210, the cathode follower of Condenser Microphone type 4111. Microphone Amplifier type 2601 and a suitable amplifier delivering at least 1 mV to the Tracer input for the lowest level to be recorded.

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Copenhagen

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